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Auditory-motor rhythm synchronization in children with autism spectrum disorder

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ABSTRACT

Background: Autism spectrum disorder (ASD) is characterized by difficulties in social and communication skills as well as atypical sensory perception and motor skills. Sensorimotor abilities such as auditory-motor integration are essential for social interaction and communication. The goal of this research was to investigate the development of auditory-motor rhythm synchronization for the first time in ASD versus typically-developing (TD) children.
Methods: Participants were 31 boys with ASD and 23 TD boys that were matched in age and IQ. Participants were tested on an auditory-motor rhythm synchronization task in which they tapped in synchrony with rhythms of varying metrical complexity.
Results: Both children with ASD and TD performed similarly on this task and both groups performed better with age.
Conclusions: This work demonstrates that non-verbal rhythm synchronization is intact in ASD over the course of childhood development. This research serves to better understand sensorimotor interactions in ASD and to better define sensory phenotypes in ASD.

1. Introduction

The coordination and regulation of sensory and movement information is essential for social interaction and communication (Donnellan, Hill, & Leary, 2012). In particular, auditory-motor integration is critical for acquiring complex skills such as speech, language and musical proficiency (Zatorre, Chen, & Penhune, 2007). However, many individuals with autism spectrum disorder (ASD) have atypical sensory (Leekam, Nieto, Libby, Wing, & Gould, 2007) and motor skills (Gowen & Hamilton, 2013; Green et al., 2009). Studies on auditory-motor integration in ASD are limited, but some work has shown impairments in the context of complex and speech-related auditory-motor tasks in ASD. However, it is unclear how individuals with ASD perform on more basic and non-verbal auditory-motor rhythm synchronization tasks. Moreover, the

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developmental course of auditory-motor rhythm synchronization is unclear in ASD. To these aims, in the present study we examined basic auditory-motor rhythm synchronization in children with ASD versus TD for the first time with a focus on age-related changes in performance.

1.1. Auditory-motor skills in ASD versus TD

In the auditory domain, individuals with ASD tend to have impaired high-level and complex sensory processing, but intact or enhanced detail-oriented processing of low-level stimuli (Mottron, Dawson, Soulières, Hubert, & Burack, 2006). For example, while the perception of complex linguistic and socially-relevant speech stimuli is often impaired in ASD compared to TD, certain aspects of musical information such as pitch discrimination may be intact or enhanced in ASD (for a review, see Ouimet, Foster, Tryfon, & Hyde, 2012; O'Connor, 2012). In the motor domain, studies have found both fine and gross motor differences in ASD (Freitag, Kleser, Schneider, & von Gontard, 2007; Green et al., 2009). For instance, fine motor abilities necessary for daily living skills have been shown to be delayed in children with ASD, as well as gross motor skills such as running and throwing (Provost, Lopez, & Heimerl, 2007; Lane, Harpster, & Heathcock, 2012).

Motor skill performance largely relies on intact sensory abilities (Tseng, Diedrichsen, Krakauer, Shadmehr, & Bastian, 2007; Shadmehr, Smith, & Krakauer, 2010; Liu, 2013). However, there has been limited study of auditory-motor integration in ASD, and most work has been conducted in the context of gross motor and complex speech tasks. For example, Moran, Foley, Parker, and Weiss (2013) examined two-legged hopping in sync with an auditory cue in young ASD adults with impaired expressive language versus TD. While TD performed well on this task, individuals with ASD were unable to regulate their motor production to match an external auditory cue. Other studies have investigated auditory-motor integration in the context of speech-related tasks. Lin et al. (2015) examined auditory-motor control in adults with ASD versus TD by delaying their speech feedback or adding loud noise to their auditory feedback. They found that performance in ASD was less affected by noise and more affected by the delayed speech feedback. These findings indicate that, in contrast to TD, individuals with ASD rely more on feedback control than on feedforward control in speech production. In another study, Russo, Larson, & Kraus (2008) examined audio-vocal regulation in children with ASD by presenting pitch-shifted voice auditory feedback to vocalizing participants. A subset of children with ASD who showed larger responses to perturbed auditory feedback also had lower receptive language scores relative to TD, signalling a possible dysfunction in the audio-vocal system for voice pitch regulation in ASD. Taken together, the studies reviewed above indicate that auditory-motor integration in ASD is altered in the context of gross motor and speech-related tasks.

Some work has begun to examine the potential of auditory-motor based therapies in ASD. For example, Wan et al. (2011) effectively used Auditory-Motor Mapping Training (AMMT) to promote speech production in non-verbal children with ASD. In another study, Srinivasan et al., 2015 showed that socially embedded movement-based contexts are valuable in promoting imitation/praxis, interpersonal synchrony, and motor performance in children with ASD. In addition, Hardy and Lagasse (2013) proposed the use of auditory rhythmic cueing to improve motor functioning in ASD. However, the authors signal the important need for more research to be conducted on auditory-motor rhythm synchronization in ASD before such clinical applications might be applied. The present study addresses this important gap between fundamental science and clinical application by examining auditory rhythm synchronization in ASD with a novel focus on the effect of development.

1.2. The effect of age on auditory-motor skills in ASD versus TD

Recent reports indicate that the interaction between movement and sound is present from birth and plays a critical role in communication at the beginning of life (for a review, see Provasi, Anderson, & Barbu-Roth, 2014). For example, children between 18 months to 4 years old are able to synchronize finger tapping to an external rhythm if the external rhythm is close to their own internal tapping tempo (Provasi & Bobin-Begue, 2003). Studies in TD have shown that rhythm synchronization and tempo discrimination improves with age (Drake, Jones, & Baruch, 2000).

Studies of auditory processing in ASD and TD have reported developmental differences in performance. In TD, pitch discrimination ability increases with age whereas in ASD, it is enhanced in childhood but then stabilizes across development (Mayer, Hannent, & Heaton, 2014). Similarly, our laboratory found enhanced abilities in auditory global-local pitch processing in ASD at younger ages (Foster et al., 2016). Moreover, while auditory echoic memory in TD takes time to develop fully into adulthood, in ASD this development stops prematurely (Erviti et al., 2014).

In terms of motor development, young children with ASD have both gross and fine motor differences that can become more pronounced with age (Lloyd, MacDonald, & Lord, 2013), but the results are mixed. In a recent longitudinal study, Travers et al. (2016) examined the developmental course of fine motor ability in ASD versus TD using a finger tapping task in which participants were asked to tap the index finger as many times as possible within 10 s. No group differences were found in childhood, but the ASD group showed slower tapping versus TD in adolescence and adulthood. In another longitudinal study, development of gross and fine motor skills, visual reception, and receptive and expressive language was investigated in infants at high and low risk for ASD (Landa & Garrett-Mayer, 2006). By as early as 14 months of age, the high risk ASD group performed worse overall, and showed a slower developmental trajectory relative to TD.

The developmental course of auditory-motor integration in ASD is unclear. As reported above, audio-vocal regulation differs in children with ASD (Russo et al., 2008). In TD, audio-vocal regulation generally improves with age (Liu, Chen, Jones, Huang, & Liu, 2011); however, it is unclear how it evolves with age in ASD. In a study by Liu (2013), the authors reported